

Improvement of Pedestrian and Bicyclist Safety: Addressing Environmental Contributing Factors

Dohyung Kim
Assistant Professor
Department of Urban and Regional Planning
California State Polytechnic University, Pomona

Abstract

Both walking and biking have attracted attentions from planners as clean transport modes reducing automobile traffic. However, high fatality and injury rates of pedestrian and bicycle crashes prevent pedestrians and bicyclists from walking and biking. By describing research efforts on the development of environmental design resolutions for Merritt Island in Brevard County, Florida, this paper presents a systematic approach to pedestrian and bicycle crash analysis and countermeasure development. Spatial analysis methods based on GIS technology identify crash concentration zones and classify the major contributing factors of crashes in the zones. Based on the analysis, this paper especially focuses on investigating on environmental contributing factors to crashes and developing countermeasures for the factors.

Introduction

Both walking and biking have got much attention as alternative transportation modes in latest transportation planning. Walking and biking also take the part of improving environment and reducing pollution as replacing automobile traffics. They ultimately contribute toward healthy, sustainable communities as promoting healthier lifestyle and social interaction. For this reason, recent trends in land use planning and urban design principles attempt to facilitate walking and biking as promoting mixed land use, dense urban development, transit oriented development, and so on. However, unsafe roads where frequent pedestrian and bicycle crashes happen, is one of biggest barriers preventing pedestrians and bicyclists from walking and biking. In 2008, 69,000 pedestrians and 52,000 bicyclists were injured (NHTSA, 2009). Although recent trend shows decline in number of crashes and fatality rate, then high fatality rate of pedestrians and bicyclists by automobile crashes still intensify the fear of pedestrians and bicyclists. NHTSA also reports 4,378 pedestrians and 716 bicyclists were killed in 2008. In general, local authorities apply the 3Es strategy for countermeasures to crashes; Enforcement for human factors, Education for socio-economic factors, and Engineering for environment factors. Of these crash reducing approaches, the engineering countermeasures including urban design and roadway design resolutions attract urban planners' attentions due to their planning components. It is important for local authorities to identify the major characteristics of contributing factors in order to apply proper engineering countermeasures. It is also crucial to identify spatial patterns of crashes and crash

concentrations zones since each concentration zone may show unique patterns that require its own customized countermeasures.

This paper introduces a development process of engineering countermeasures addressing crashes mainly influenced by the environmental conditions of crash locations. Through a case study of Merritt Island in Brevard County, Florida, this paper investigates a logical procedure of crash mapping, identification of crash concentration zones, the identification of major environmental characteristics causing crashes in a particular zone, and the development of countermeasures dealing with the crashes in the zone. Although this paper reviews the overview of the complete process, this paper will emphasize on the identification of environmental contributing factors and the development of countermeasures for the factors, since the crash mapping and hotspot analysis methods employed for this research are comparable to preceding research (Bejleri et al, 2007; Pulugurtha et al, 2005; Ragland et al, 2003; Saxona et al, 1990; Schneider et al, 2001; Steiner et al, 2003; Ziari and Khabir, 2005)

Review of Literature

Because highway safety is an important issue, significant research has been conducted on the mapping and analyzing crashes from a variety of different perspectives including transportation planning, civil engineering, psychology, and medical science. A variety of the research topics have been intensively researched such as crash mapping using Geographic Information Systems (GIS) and crash hotspot identification methodology development. One of those research topics is to investigate the spatial patterns of factors contributing to bicycle and pedestrian crashes. Research has identified three main contributing factors to bicycle and pedestrian crashes, human factors, socio-economic factors, and environment factors.

Some of these researchers that focus on human factors attempt to understand the characteristics and behaviors of drivers and pedestrians involved in crashes, such as child and elderly populations, and discuss the specific vulnerability of specific populations (Harruff et al, 1998; Koespell et al, 2002; Turner, 2000). Identifying the type of people involved in crashes, Rivara (1990) points out that males have a rate of pedestrian injuries and fatalities nearly twice that of females. Harruff et al. (1998) reported high correlation between fatality and alcohol consumption based on 217 pedestrian crashes in Seattle, Washington. Kiburz et al (1986) determined bicycle use and crash patterns by analyzing a survey of about 500 active adult bicyclists. They listed contributing behavioral factors to bicycle crashes such as rider carelessness, cycle malfunction, turns and hills, and companion riders. Other studies focus on bicycle helmet use and safety impact. One such study determined that head injury is the primary or contributing factor in 70% to 85% of bicycle-related deaths (Fife et al, 1983).

Other studies identify the contributing factors of the crashes based upon the socio-economic characteristics of the surrounding areas. Podkowiec (1991) describes land development and traffic influences on road accidents. Graham and Glaister (2002) find evidence to support a strong correlation between childhood pedestrian fatalities and more deprived areas, and they also point out correlation between pedestrian crashes and densely populated areas. Pawlovich et al. (1998) conduct regression analysis between demographic and socio-economic data and crashes. They pointed out the strong correlation between crashes and several variables; persons 3 years and over enrolled in

pre-primary school; workers 16 years and over who do not work at home and whose travel time to work was 10-14 minutes; and employed persons 16 years and over who are in sales occupations.

Finally, some studies identify the contributing factors from environmental factors and roadway features of crash locations. Environmental factors refer to facility design faults as well as the speed and type of traffic. The correlation between speed and injury severity has been studied (Bicycle Federation of America Campaign, 1998; Campbell et al, 2004). These studies conclude that a ten-mile-per-hour increase in speed, from 20 mph to 30 mph, increases the risk of death nine-fold for a pedestrian in a collision. Analyzing 5,000 crashes in U.S., Hunter et al. (1996) analyzed 5,000 crashes in the U.S. and notes that 75% of pedestrian crashes occur where speed limits are less than 35 mph. The Pedestrian and Bike Crash Analysis Tool (PBCAT), analyzes the details of crash types such as when and where crashes occur and the characteristics and actions of pedestrian or bicyclist involved in the crash. PBCAT, which was developed by the University of North Carolina Highway Safety Research Center, can be used manually or through the use of a software program (Pedestrian and Bicycle Information Center, 2009).

While most research focuses on categorizing and finding the contributing factors, strategies on providing countermeasures are less well developed. In general, local authorities employ the 3Es strategy (Enforcement, Education, and Engineering) in order to address crashes occurred by different types of contributing factors. The enforcement is an efficient method soothing crashes influenced by human behavior factors such as drinking related crashes and crashes happening to specific population like child and elderly population. The education program address crashes mainly caused by socio-economic characteristics of crash locations such as crashes in deprived neighborhood and high crash concentration in areas with low automobile ownership. Finally, the engineering is utilized to address crashes triggered by environmental conditions of crash locations including speed limits of roadways, conditions of pedestrian facilities, and existence of bike lanes. Partly because crashes are influenced by the interaction of various factors and partly because there are not many studies introducing methods of countermeasure development, all of three countermeasures are usually mix-used. However, it is necessary to clarify the type of major contributing factors in a particular crash concentration zone, and implement customized countermeasures to the zone. This approach contributes toward efficient allocation of scarce resources as making it possible to limit inappropriate resolutions beforehand.

Project Context

Making Brevard County, Florida a place where it is a pleasure to walk and bicycle is a commendable goal for the County's Bicycle, Pedestrian, and Trail Master Plan. The benefits of such a place promote healthier lifestyles and social interaction; and provide opportunities for recreation and real transportation choices beyond the automobile for getting to daily destinations. The MPO identified a need for bicycle and pedestrian education, as well as encouraging local governments to require the inclusion of pedestrian and bicycle facilities in their site review process. The MPO also wants to help the County and local governments address land use and urban design factors that can further promote bicycling and walking. Whether this is through retrofitting existing areas or through careful review of proposed new developments, localities need the tools to

effectively and creatively transform the physical environment in support of creating more walkable and bikeable communities. As a first step to achieve this goal, this project attempted to identify crash concentration zones, which especially had high correlation with physical environments, and developed possible urban design and landscape resolutions for contributing factors. This project started with mapping pedestrian and bicycle crashes of two years, and identified countywide crash hotspots using cutting-edge GIS technology. Of the hotspots, it selected one hotspot mostly influenced by environmental contributing factors. Then, it analyzed the environmental conditions of the hotspot and develops appropriate countermeasures for the hotspot.

Selection of the Study Area; Merritt Island

Crash mapping refers to an effort that identifies locations of crash data so that pattern of the crashes can be analyzed. Mapping crashes in GIS is an important process that converts text data or tabular data to spatial data that locates crashes on a roadway map. Geo-referenced crash data can be utilized for a wide range of spatial analysis including identification of crash hotspots, spatial pattern and trend analysis as well as data visualization. Utilizing GIS technology, two years of bicycle and pedestrian crashes (2004-2005) have been mapped (Figure 1). 597 out of total 640 reported crashes were successfully mapped. Through crash mapping and spatial analysis such as density analysis and linear summary analysis, several crash concentration zones were identified.

Among those crash concentration zones, Merritt Island was selected for further study due to its unique crash pattern. Observations suggest that hotspots influenced by environmental factors show linear cluster and ones impacted by socio-economic factors turn to be polygonal shapes (Bejleri, et. al., 2007). Human factors tend to be random spatial distribution. The Merritt Island hotspot presents strong linear distribution of crashes. Total 31 crashes occurred in the Merritt Island hotspot. Of the total crashes, 21 crashes occurred on two major arterials, Merritt Island Causeway and Courtney Parkway. This pattern, about 68 % of crashes concentrating on only two roadways, represents strong linear cluster of crashes rather than polygonal cluster. Another reason for selecting the Merritt Island hotspot was the similarity of socio-economic conditions on Merritt Island Causeway and Courtney Parkway. They are geographically close to each other (as a matter of fact, they intersect each other). Furthermore, the land use patterns and socio-economic characteristics along them are very similar to each other. However, the crash distribution between Merritt Island Causeway and Courtney Parkway was skewed. 14 crashes out of 21 crashes occurred on Courtney Parkway, while the other 7 crashes occur along Merritt Island Causeway. Since the total length of the streets are 1.32 miles and 2.28 miles accordingly, the crashes per mile along Courtney Parkway are 10.61 and the crashes per mile along Merritt Island Causeway are 3.07. Therefore, this incomparable difference of crash frequency between those two corridors can be only explained with the difference of physical environments along those corridors rather than the socio-economic conditions.

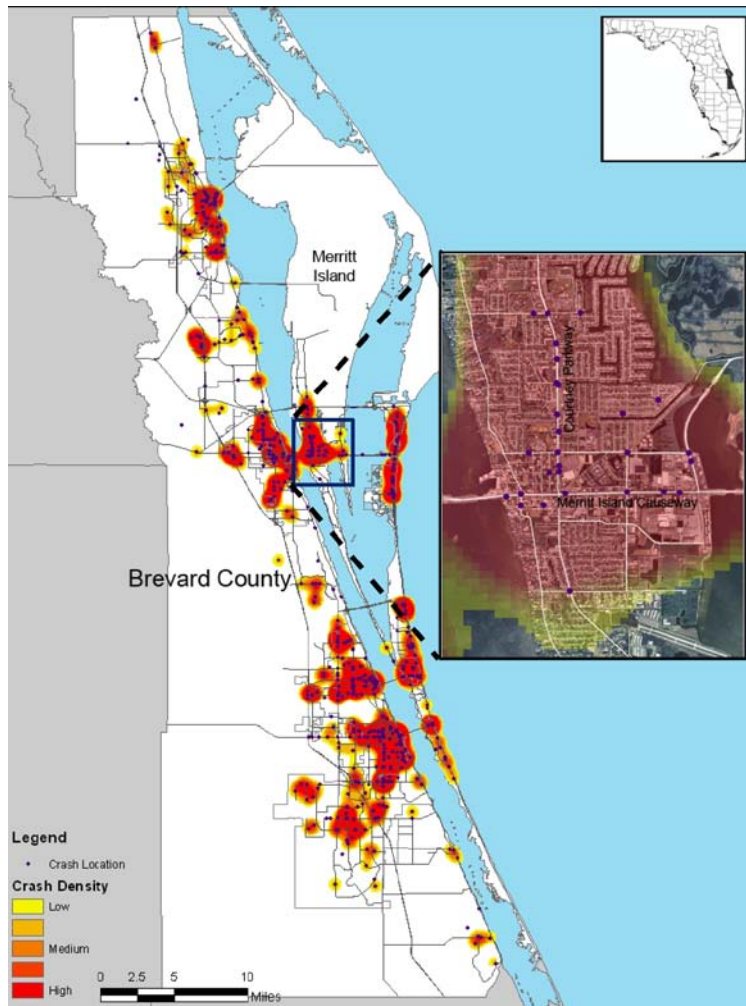


Figure 1. Crash concentration zones in Brevard County and Merritt Island study area

Analysis of Environmental Conditions

Due to the skewed crash distribution between Courtney Parkway and Merritt Island Causeway, this research was naturally led to comparison of environmental conditions on two corridors. GIS technology and field observation were employed for the comparison. GIS technology supports to quantify the environmental conditions and create spatial data inventory for analysis. Throughout this analysis, it was identified that the roadway characteristics of two corridors including speed limit, number of lanes, functional class, and right of way were equivalent to each other, while showing remarkable contradictions in pedestrian and bicycle facilities. Four major contradictions were pedestrian and bicycle accessibility, sidewalk characteristics, sidewalk amenities, and crosswalk environments.

Pedestrian and Bicycle Accessibility

In general, Courtney Parkway and Merritt Island Causeway have typical settings of major regional arterials such as regional big box stores and strip malls along the corridors, mixes of offices and retail shops surrounded by multi-family housing units, and single family subdivisions at the fringe of the area. This high rate of mixed land use

pattern provides excellent walking and biking opportunities to local residents. However, high propensity of walking and biking is obviously correlated to high crashes. One way to avoid this correlation is to have multiple travel routes from destinations to destinations, which make it possible to separate bicycle and pedestrian flows from major automobile travel routes. In other words, if bicyclists and pedestrians are able to travel along streets less automobile traffic, there are fewer chances of crashes.

Merritt Island Causeway has much more options of travel routes than Courtney Parkway does. There are few neighborhood characteristics along Courtney Parkway that make it difficult to obtain multiple travel options. First characteristic is a canal system located at the northeast corner of the study area. Due to limited local paths between blocks in the neighborhood caused by a canal system surrounding the single family residential areas at the corner, the residents in the area have limited travel routes the neighborhood other than major automobile routes. The second issue is gated communities located at the northwest corner of the area. The gated communities taking large area of the corner do not allow bicycles and pedestrians to pass through their communities. Therefore, bicycles and pedestrians only have limited travel routes in the neighborhood. The last characteristic is public facilities surrounded by fences. There are three schools and one recreational facility in the neighborhood. Like the gated communities, the public facilities in the neighborhood are surrounded by fences. Ironically, those public facilities that attract a lot of bicycle and pedestrian trips turn out to taking away travel alternatives from bicyclists and pedestrians. Contrast to Courtney Parkway, the neighborhood along Merritt Causeway has no such barriers. The neighborhood has well connected local streets which allow bicycles and pedestrians to travel to destinations without encountering heavy automobile traffic.

Sidewalk Conditions

There are no bike lanes along both Courtney Parkway and Merritt Island Causeway. Sidewalks are main facilities that both bicycles and pedestrians travel. For this reason, the conditions of sidewalks get more closely related to the safety of bicycles and pedestrians. Table 1 illustrates contrast conditions of sidewalks between Courtney Parkway and Merritt Island Causeway.

Sidewalks along Courtney Parkway have 81 times of sidewalk discontinuations (in average, 33.6 discontinuations per mile), while ones along Merritt Island Causeway have 69 times (22 per mile). These discontinuations are mostly caused by parking lot entranceways, which provide great chances of conflict between pedestrian/bicycle and automobile traffic. In ratio, more than two times of sidewalks along Courtney Parkway (28.6%) than ones along Merritt Island Parkway (13.7%) are lost for parking lot entranceways. As one entranceway to a gas station on Courtney Parkway takes over about 192 feet of sidewalk, the entranceway erases the sidewalk, which is, in dimension, wider than a divided highway with 8 lanes, providing no protections to pedestrians and bicycles at all.

Table 1. The conditions of Sidewalk and Crosswalks

			Courtney Parkway	Merritt Island Causeway
Sidewalk Environment	Total Length of Sidewalks (mi)		2.41	3.14
	Sidewalk Discontinuation	Total Number	81	69
		Per Mile	33.6	22.0
		Total Length	0.70	0.43
		Ratio to Total Length of Sidewalks (%)	29.0	13.7
		Mean Length (ft)	45.4	33.0
		Length of the Longest (ft)	192.1	75.5
Crosswalk Environment	Median	Total Length (mi)	0.71	0.97
		Ratio to Total Length of Roadways (%)	53.8	42.5
	Signalized Intersection	Total Number	5	6
		Per Mile	3.79	2.63
	3 Way Junction	Total Number	15	8
		Per Mile	11.36	3.51

Landscape of Sidewalks

It is not straightforward to quantify the landscape of sidewalks. Unlike sidewalk characteristics, it seems that the landscape is not directly related to pedestrian and bicycle safety issues. However, the landscape is an important factor for the safety in terms of providing physical and psychological shelters to pedestrians and bicycles. Well defined planters, street tree line, street furniture cannot only offer shelters or hiding places for pedestrians or bicycles when an emergency situation occurs, but also make it possible for them to feel safe. Thus, the well established landscape of sidewalks makes communities more walkable.

The Courtney Parkway and Merritt Island Causeway case presents an outstanding example of roles of sidewalk landscape on pedestrian/bicycle safety. Large portion of Merritt Island Causeway is decorated with planters and aligned street trees along sidewalks, holds extra green spaces between sidewalks and parking lots, and is placed with proper street furniture including benches and shaded bus stops. In contrast, Courtney Parkway absolutely lacks all of the amenities: it is hard to distinguish sidewalks from parking lots along most portion of Courtney Parkway, narrow sidewalks are located right next to parking lots, and unorganized street light poles block pedestrian and bicycle flow. Figure 2 illustrates typical appearance of sidewalks on both Courtney Parkway and Merritt Island Causeway. Those pictures are probably eligible evidences demonstrating the difference of landscape conditions of those two corridors.

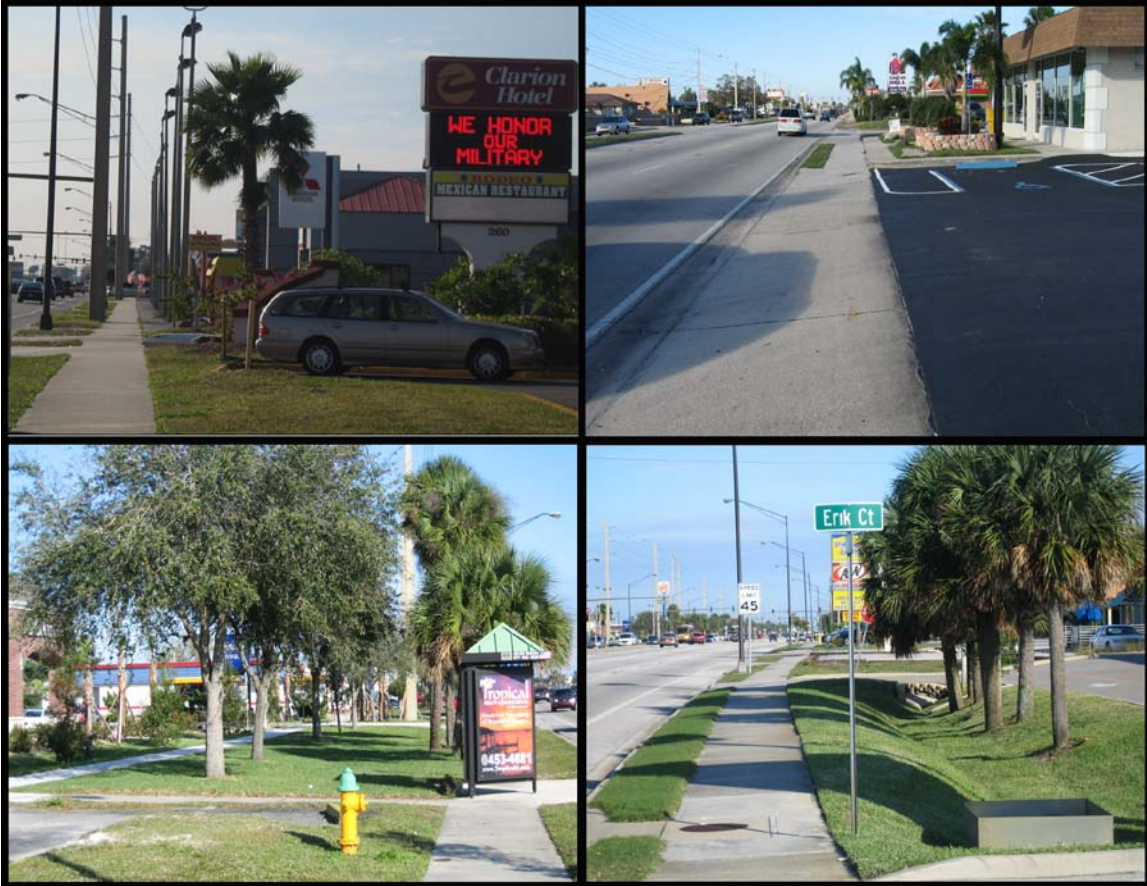


Figure 2. Typical conditions of sidewalks

Two photos on the top illustrate the conditions of Courtney Parkway and the bottom two photos are from Merritt Island Causeway.

Crosswalk Conditions

Crashes tend to occur more often when pedestrians and bicycles cross streets as they intermingle with automobiles. It is also observed that crashes occurred during pedestrians and bicyclists cross roads show high fatality and severe injuries. Therefore, it is important to provide safe facilities such as signalized crosswalks and medians for pedestrians and bicyclists to safely cross roads.

As comparing crosswalk conditions of Courtney Parkway and Merritt Island Causeway, some similarities and differences were recognized. Although there are similar numbers of signalized intersections and similar length of median on both corridors, numbers of three-way junctions present great difference between them (Courtney Parkway; 15 and Merritt Island Causeway; 8) (Table 1). Therefore, a pedestrian or a bicyclist comes across 11.36 three-way junctions every mile he or she walk or bike along Courtney Parkway, while he or she does 3.51 three-way junctions along Merritt Island Causeway. Furthermore, the junctions becomedangerous spots since none of them are signalized. The expose of pedestrians and bicyclists to these dangerous spots contributes toward the high crash rate along Courtney Parkway.

Development of Countermeasures

The physical conditions of Courtney Parkway are much more dangerous and unpleasant for pedestrians and bicyclists compared to ones along Merritt Island Causeway. Based on the analysis of the environmental conditions, numerous design resolutions were reviewed from comprehensive design guidelines to minor landscaping options. As the County searches practical, realistic, and yet efficient design solutions, however, the general direction of countermeasure development was led to applying incremental improvements of bicycle and pedestrian facilities. The County was especially interested in duplicating the positive environment characteristics of Merritt Island Causeway to Courtney Parkway because the County was impressed by relatively low crash frequency on Merritt Island Causeway.

Development of Alternative Pedestrian and Bicycle Routes

Providing pedestrian and bicycle oriented streets connecting major destinations will be an ultimate resolution to reduce crashes. As reducing chances that pedestrians/bicyclists encounter automobile, crashes can be avoided. Several streets around Courtney Parkway, which possess great potential to be alternative routes, were identified. In addition to existing streets having potential as pedestrian and bicycle oriented travel routes, the map also illustrates possible new roadways (Figure 3).

McLeod Street is a perfect example for this case. McLeod Street connecting Merritt Island Causeway and Mila elementary school is well equipped with traffic calming devices such as speed bumps and newly added medians with palm trees. This street can be a perfect place for bike lanes and an ideal route for pedestrians who want to avoid busy Courtney Parkway, but on-street parking lots, instead of bike lanes, take space next to sidewalks. Moreover, there are no sidewalks on Merritt Avenue which leads McLeod Street to the school and surrounding residential areas. If bike lanes and sidewalks are added to McLeod Street and Merritt Avenue accordingly, they will contribute toward the separation of pedestrian and bicyclist flow from major automobile traffic along Courtney Parkway. They will also serve for children who go to Mila elementary school as a safe route to school.

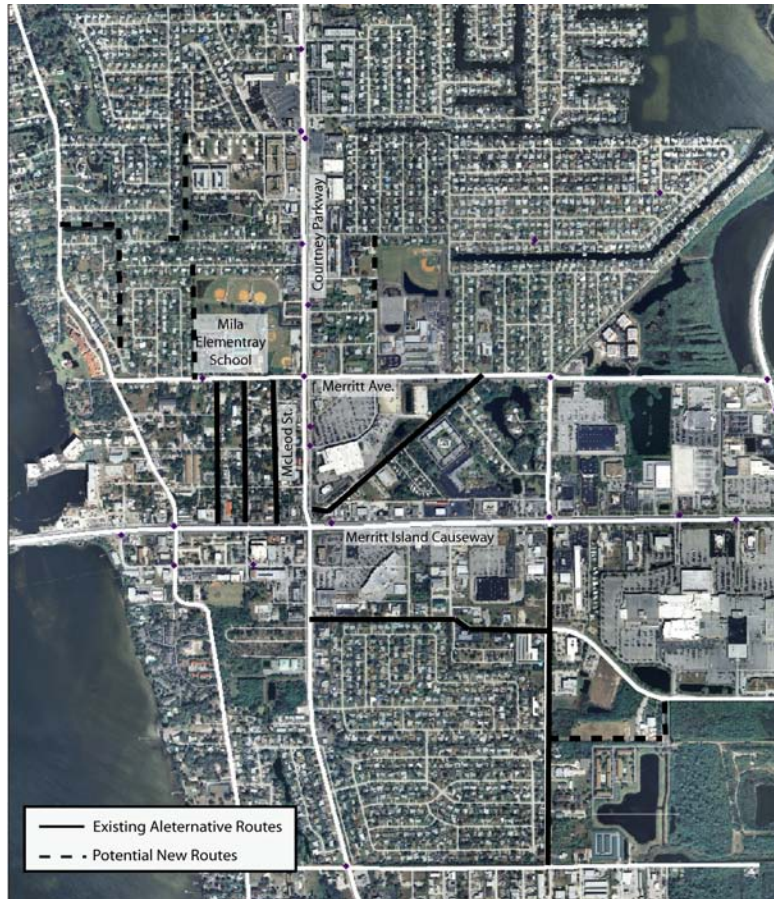


Figure 3. Alternative pedestrian and bicycle routes

Parking Lot Access Control

As pointed earlier, the discontinuation of sidewalks is one factor displaying great difference between Courtney Parkway and Merritt Island Causeway. In order to address this issue, it is necessary to restore sidewalks on parking lot entrance ways. On the other hand, however, parking lot entrance ways are necessity for businesses along Courtney Parkway. This dilemma makes difficult to control parking lot entrance ways. However, conscientious investigation identified many cases that one parking lot had multiple parking lot entrance ways. In these cases, reducing number of parking lot entranceways will not cause any serious impacts on the traffics in and out the parking lots

Figure 4 illustrates the current conditions and possible improvements of controlled parking lot entrance ways. In this case, four parking lot entrance ways (232 feet) can be reduced to one (60 feet). When this strategy is applied to the whole Courtney Parkway corridor, twenty eight out of total eighty one discontinued segments (34.6%) can be converted back to sidewalk. This means that the total 0.26 mile of sidewalks, which is 36.6% of total discontinued sidewalks are able to be restored. Thus, the discontinuation of sidewalks will be reduced from 0.7 mile to 0.44 mile. Then, the discontinuation rate of sidewalks of Courtney Parkway (18.3%) becomes close to one of Merritt Island Causeway (13.7%).

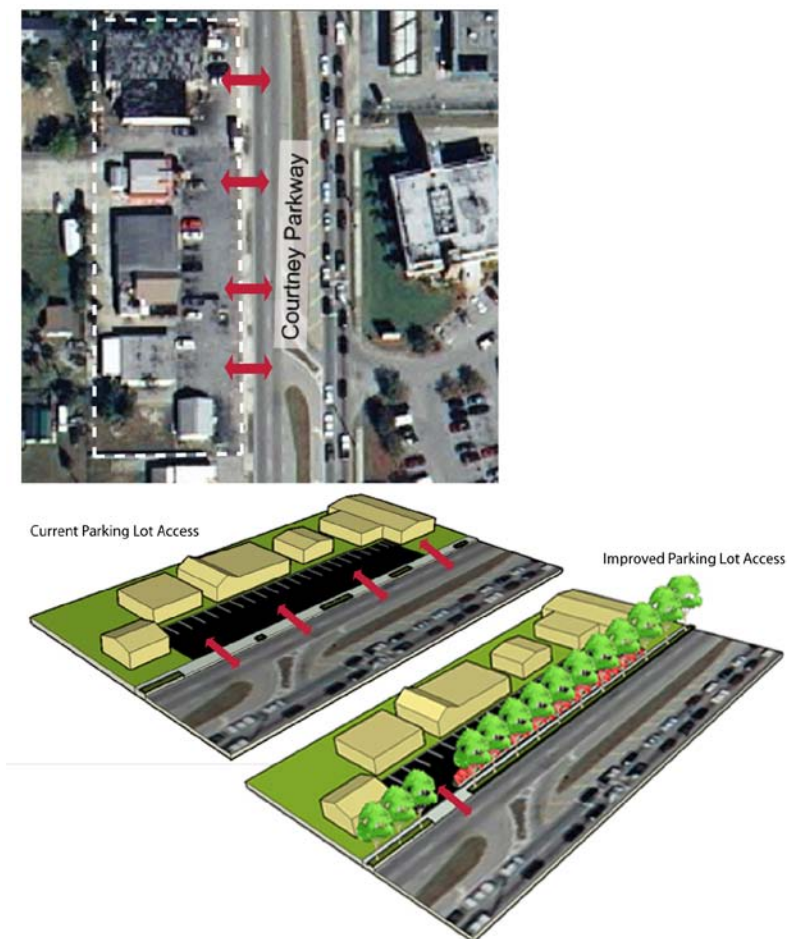


Figure 4. Example of improved parking lot access control

Street Landscaping

Street landscape provides physical and metal protection to pedestrians and bicyclists. Street landscape is a relatively simple resolution yet very effective. Unlike ordinary landscape which focuses on beautification, the landscaping planned for Courtney Parkway must consider pedestrian and bicycle safety issues as well as beautification. Few considerable design points were recommended.

The first landscape design recommended was to build curbs on sidewalks, which meet parking lot entrance ways. Currently there are no levels or borders between most of parking lot entrance ways and sidewalks. Automobiles passing through the entrance ways overrun to sidewalks without any barriers, and pedestrians and bicyclists walk and bike without recognizing that they are in dangerous zones. The curbs differentiating levels between the sidewalks and the entrance ways will prevent automobiles from invading to the sidewalks as well as warning pedestrians and bicyclists as they walk or bike into the entrance ways. Second, it is necessary to create planters between sidewalks and parking lots in order to physically separate pedestrians and bicyclists on sidewalks from

automobiles in parking lots. Large portion of sidewalks on Courtney Parkway is barely distinguishable from parking lots. Of little less than 1 mile, precisely 0.95 mile, of the sidewalk located right next to parking lots, only 0.53 mile (55.8%) of the sidewalk have physical buffers such as lawn or walls from parking lots. The other 0.42 mile of the sidewalk has no clear separation from parking lots. Creating planters between the sidewalks and the parking lots is a practical resolution since there is not much space between the sidewalks and parking lots. Third, planting street trees along sidewalks offers protective walls to pedestrians and bicyclists. Currently, there is existing lawn along Courtney Parkway, but there are no trees planted. Therefore, planting trees is relatively easy to implement. Figure 5 illustrates a typical street segment's current and improved environments as recommended above.



Figure 5. Example of improved sidewalk landscapes

Signs and Signals

Courtney Parkway has relatively well established medians and signalized crosswalks for all major intersections. However, the conditions of 3 way junctions are not in a good shape. Only three out of total fifteen 3-way junctions (20%) have crosswalks, while three of eight on Merritt Island Causeway (37.5%) have crosswalks. None of them are signalized. There are also no pedestrian and bicycle signs existing on Courtney Parkway. Although the speed limit of most of 3-way junction is 25 miles per hour, they are still the place where pedestrians and bicycles run into each other. Therefore, providing proper crosswalks and signs is crucial to control behaviors of automobiles as well as pedestrians and bicycles at the 3-way junctions.

Conclusion

Pedestrian and bicycle crashes by motor vehicles are one of biggest barriers preventing people from walking and biking; furthermore, they jeopardize healthy, sustainable communities. However, it is not straightforward to find resolutions to reduce the crashes due to the crashes caused by the interactions of various contributing factors. The case study on Courtney Parkway in Brevard County, Florida illustrates the complete process that develops countermeasures for pedestrian and bicycle crashes influenced by the environmental conditions. Crash mapping and the identification of crash concentration zones using GIS technology make it possible to focus on analyzing crash patterns in each problematic area. Analysis on spatial patterns of crashes in crash concentration zones provides clues for characteristics of major contributing factors in the zones. From this perspective, the Merritt Island case is such a unique example explaining how environmental conditions influence to pedestrian and bicycle crashes since Merritt Island Causeway and Courtney Parkway present remarkable difference in crash frequency although they are geographically close to each other. As comparing the environmental conditions on those streets, it becomes clear that the availability of the pedestrian and bicycle oriented paths, conditions of sidewalks, amenities of sidewalks, and conditions of crosswalks are main environmental contributing factors for crashes occurred on Courtney Parkway. Based on the understanding on these current conditions, several countermeasures duplicating the environmental conditions of Merritt Island Causeway to Courtney Parkway are suggested.

Many physical and political restrictions make it difficult to implement comprehensive design and engineering improvements to already built areas. With understanding on these restrictions, local authorities focus on finding efficient incremental design resolutions to reduce crashes in built area. As the Merritt Island case illustrates, there is big possibility to reduce number of pedestrian and bicycle crashes with minor updates on pedestrian and bicycle facilities. Thus, it is necessary for local authorities to keep putting efforts on identifying the characteristics of contributing factors of local pedestrian and bicycle crashes and generating minor, yet efficient countermeasures for the crashes.

References

- Bejleri, I., Steiner, R., and Kim, D. GIS methods and tools for bicycle and pedestrian crash mapping and analysis. *86th Annual Transportation Research Board Meeting*, January 21-25, 2007, Washington D.C.
- Bicycle Federation of America Campaign (BFA) to Make America Walkable. *Creating walkable communities-a guide for local government*. Prepared for the Mid-American Regional Planning Council, 1998.
- Campbell, B., Zegger, C., Huang, H., and Cynecki, M. *A review of pedestrian safety research in the United States and abroad*. U.S. Department of Transportation Federal Highway Administration, FHWA-RD-03-042, 2004.
- Fife, D., Tate, L., Wells, JK., Mohan, D., and Williams, A. Fatal injuries to bicyclists: the experience of Dade County, Florida. *Journal of Trauma Injury Infection and Critical Care*, Vol. 23, No. 8., 1983, pp. 745-755
- Graham, D. and Glaister, G. *Spatial variation in road pedestrian casualties" the role of urban scale, density and land use mix*. Imperial College Centre for Transport Studies, working paper, 2002
- Harruff, R., Avery, A., and Alter-Pandya, A. Analysis of circumstances and injuries in 217 pedestrian traffic fatalities. *Accident Analysis and Prevention*, Vol. 30, No. 1, 1998, pp. 11-20.
- Hunter, W., Stutts, J., Pein, W., and Cox, C. *Pedestrian and bicycle crash types of the early 1990's*. Department of Transportation Federal Highway Administration, FHWA-RD-95-163, 1996.
- Kiburz, D., Jacob, R., Reckling, F., and Madison, J. Bicycle accidents and injuries among adult cyclists. *American Journal of Sports Medicine*, Vol. 14, No. 5, 1986, pp. 416-419.
- Koespell, T., McCloskey, L., Wolf, M., Moudon, A., Buchner, D., Kraus, J., and Patterson, M. Crosswalk markings and the risk of pedestrian-motor vehicle collisions in older pedestrians. *Journal of the American Medical Association*, Vol. 288, No. 17, 2002, pp. 2136-2143.
- National Highway Safety Administration (NHTSA). *Traffic Safety Facts*, 2009.
- Pawlovich, M., Souleyrette, R., and Strauss, T. A methodology for studying crash dependence on demographic and socioeconomic data. *The Proceedings of Crossroads 2000 Conference*, August 19-20, 1998, Ames, Iowa.
- Pedestrian and Bicycle Information Center (PBIC). 2006. *What is PBCAT?* <http://www.walkinginfo.org/facts/pbcats/index.cfm>, Accessed on Aug 10, 2009
- Podkowicz, C. The influence of land development and traffic on road accidents. *Transportation Quarterly*, Vol. 3, No. 2, 1991,
- Pulugurtha, S., Nambisan, S., and Uddaraju, M. Methods to rank high pedestrian crash zones. *84th Annual Transportation Research Board Meeting*, January 22-26, 2005, Washington D.C.
- Ragland, D., Markowitz, F., and MacLeod, K. *An intensive pedestrian safety engineering study using computerized crash analysis*. Institute of Transportation Studies, University of California Berkeley Traffic Safety Center. Paper UCB-TSC-RR-2003-12, 2003

- Rivara, F. Child pedestrian injuries in the United States: current status of the problem, potential interventions, and future research needs, *American Journal of Diseases of Children*, Vol. 144, No. 6, 1990.
- Saxena, A., Babu, G., Bajpai, R., and Sarin, S. GIS as an aid to identify accidents patterns. *The Proceedings of 5th International Map India Conference*, February, 6-8, 2002, New Delhi, India.
- Schneider, R., Khattak, A., and Zegger, C. Method of improving pedestrian safety proactively with Geographic Information Systems. *Transportation Research Record*, No. 1773, 2001, pp. 97-107.
- Steiner, R., Bejleri, I., Yang, X., and Kim, D. 2003. Improving geocoding of traffic crashes using a custom ArcGIS address matching application. *The proceedings of 23rd Annual ESRI International User Conference*. July 7 –11, San Diego, CA.
- Turner, P. *Making crosswalk safer for pedestrians*. Center for Urban Transportation Research, University of South Florida, Report No. BCO10, 2000.
- Ziari, H. and Khabiri, M. Applied GIS software for improving pedestrian & bicycle safety. *Transport*, Vol. 20, No. 4, 2005, pp. 160-164.